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Felicitats a la nova graduada de doctorat de l'ICFO

La Dra. Sandra Buob s'ha doctorat amb una tesi titulada ï¿½ Quantum-gas microscopy of strontium Bose- and Fermi-Hubbard systemsï¿½

November 22, 2024

Felicitem a la Dra. Sandra Buob que aquest mati ha defensat la seva tesi a l'Auditori de l'ICFO. La Dra. Buob va obtenir el Master en Fisica per ETH Zürich a Suissa. Es va unir a l'equi d'investigacioUltracold Quantum Gases dirigit per la professora ICREA Dra. Leticia Tarruell. La seva tesi titulada "Quantum-gas microscopy of strontium Bose- and Fermi-Hubbard systems" va ser dirigida per la professora ICREA Dra. Leticia Tarruell.

RESUMEN:

Ultracold atoms have proven to be a valuable asset to study and understand complex quantum many-body systems in a well-controlled setting. In particular, quantum-gas microscopes provide unprecedented access to local observables and allow one to investigate those systems at the level of each individual particle, giving new insights on their behaviour. While so far most of these microscopes used alkali atoms, the distinct properties of alkaline-earth atoms, in particular strontium, combined with quantum-gas microscopy are expected to shed new light on a broad variety of many-body problems. This thesis describes the realization of single-site-resolved imaging for both bosonic and fermionic strontium atoms in a Hubbard-regime optical lattice, which unlocks the possibility to study novel types of Bose- and SU(N) Fermi-Hubbard systems.

An essential step in ultracold-atom experiments is the preparation of a quantum degenerate cloud. In the first part of this thesis, we discuss the methods we have implemented in our apparatus to achieve this goal. We developed a new resonant-shielding method to double the atom number during the first cooling stage in a broad-linewidth blue magneto-optical trap. During the second cooling stage in a narrow-linewidth red magneto-optical trap, the hyperfine structure of the fermionic atoms adds additional challenges which are addressed by mixing the hyperfine states with an additional laser for efficient trapping and cooling. After the laser-cooling stages, we perform evaporative cooling in a far red-detuned optical potential before loading the atoms into a two-dimensional optical lattice. The lattice laser operates at the clock-magic wavelength of strontium (813.4nm) which will enable

high-precision measurements in future experiments.
To image the individual atoms in the optical lattice, we place a high-NA objective in close vicinity to the atoms. We demonstrate single-atom resolution for bosonic and fermionic strontium and successfully reconstruct the lattice occupation for both of them, reaching fidelities as high as 96%. For the bosonic Sr-84 atoms, we induce fluorescence on the blue broad-linewidth transition and simultaneously perform attractive Sisyphus cooling on the red narrow-linewidth transition. Moreover, combining this imaging method with momentum-space detection, we observe the matter-wave interference arising from the phase coherence of the Bose-Hubbard superfluid. For the fermionic Sr-87 atoms, we image with the red transition only, which allows us to obtain for the first time for a fermionic alkaline-earth atom both single-atom resolution and spin-resolved detection.
This thesis has combined, for the first time, quantum-gas microscopy with ultracold strontium and its distinct spectral properties. This platform should enable a broad range of future studies. For the bosons, it unlocks investigation of the single-atom-resolved dissipative Bose-Hubbard systems and the exploration of collective atom-photon scattering in ordered atomic arrays. For the fermions, the spin-dependent single-atom detection provides the ideal setting for investigations of antiferromagnetic correlations in SU(N?10) Fermi-Hubbard systems and the realization of exotic magnetic phases.

Comissio de Tesi:

Prof. Dr. Tilman Esslinger, ETH Züric
Dr. Pablo Loza, ICF
Prof. Dr. Christian GroSs, Eberhard Karls Universitat Tübingen

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